TECHNICAL REPORT # 14

From: The Crawford Hill VHF Club, W2NFA

Date: August 1973

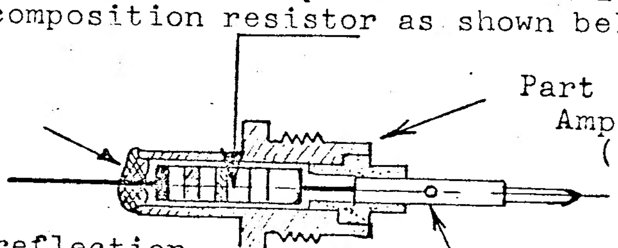
Subject: A HIGH POWER DIRECTIONAL COUPLER AND POWER MONITOR

A necessary adjunct in the EME station is a high power in-line power monitor which may also be used as a directional coupler to measure reflected power from the antenna. Two 50 ohm designs are presented in this report which are relatively easy to construct from readily available materials. The basic design is for a nominal coupling coefficient of -40 db which is useful for measuring high power levels with low power measuring equipment. For example 500 watts of available power will produce 0.05 watts in the -40 db coupled port. The coupling coefficient may be altered in this design by as much as ±20 db without violating the basic design.

The coupler consists of two 50 ohm unbalanced transmission lines weakly coupled. One line called the main line can handle hundreds of watts of power while the other line called the coupled line is only required to handle less than one watt. The couplers are built as 4-port networks with all 4 ports available. This means that for proper use external termination and detector must be used. The reason for not including the termination and detector on the coupled line is to facilitate accurate calibration at low power levels and to increase its usefulness as a measuring tool.

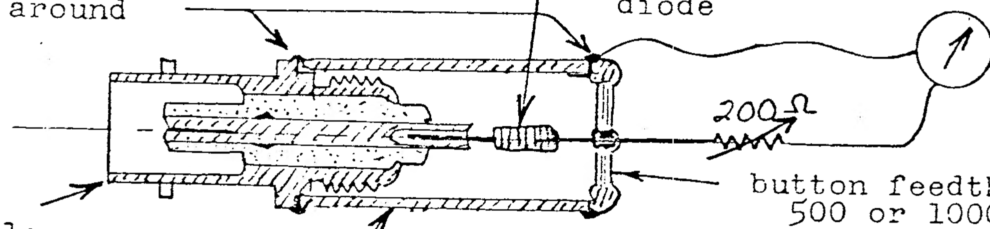
Other uses include measuring reflected power on feed lines, feeds and other devices and also to monitor the reflection coefficient while adjusting a device such as an antenna for best 50 ohm impedance match. These measurements can be performed at very low power levels using a well shielded receiver as the detector. A shielded r-f source is also advisable especially when adjusting antennas as direct r-f leakage can cause considerable error in readings.

A suitable low power termination for the 4th or null port of the coupler can be made from a specific BNC cable connector and a 47 ohm **1/2** watt 5% composition resistor as shown below.



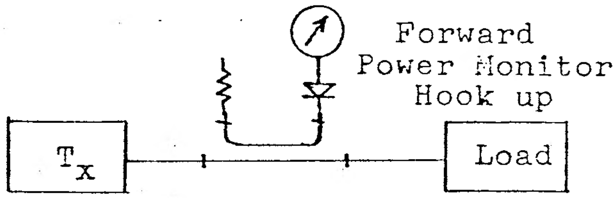
Typical reflection from this termination is -25 db at 1296 mc/s

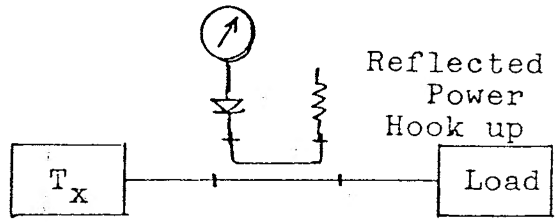
A suitable crystal detector for high power monitor may also be constructed as shown below, however any available detector suitable for UHF may be used.



Using the Coupler

As a power monitor the coupler may be installed at the output of a power amplifier with extremely little loss. This arrangement will permit continual monitor of output power. The coupler is hooked up as shown below.





To check reflected power, simply reverse the connections to the coupled line. In the designs described later, one coupler has a rotatable coupling loop while the other may be built with two coupled lines for continuous monitoring of power flow in both directions. The same hook ups apply to low power measurements where a receiver is substituted for the crystal detector.

Calibration

This coupler is not self calibrating or are the dimensions accurate enough to predetermine the coupling coefficient. In lieu of calibrated laboratory equipment properly used, the EME enthusiast can perform the coupling coefficient calibration in a variety of ways. The accuracy of these ways depends largely on how carefully the measurements are performed and what confidence can be attached to the equipment used. All methods must depend on a calibrated attenuator (±0.5 db accuracy) whether it be at UHF, IF or AF. Accurate attenuation measurement over a wide dynamic range (40 db in this case) are subject to non-linearities (saturation limiting) in the equipment as well as impedance mismatch in the circuits at either end of the calibrated attenuator. The experimenter is advised to acquaint himself with these problems of measurement before attempting accurate calibration.

One method which uses readily available equipment will be described. Most V-O-M meters are equipped with a decibel scale for AF measurement. This method will use the V-O-M as a calibrated decibel indicator in lieu of a calibrated attenuator. Particular attention must be given to saturation of equipment with this method since the station receiver will be used. The receiver must be operated in a linear mode, i.e. AVC-OFF, BFO-ON, Wide bandwidth, AF and RF gain settings for minimum saturation. A shielded low power source at 1296 mc/s is required which includes a crude adjustable output level, a variable link or adjustable capacitor output coupling will suffice.

Since the V-O-M scale is accurate only over a 10 db range it will be necessary to cover the 40 db range in four 10 db steps. In this way the receiver is only required to be linear over a 10 db range.

The calibration procedure then goes as follows:

1. Connect an adjustable low level signal source (1296 mc/s) to the coupler main line.

2. Connect receiver to other end of main line with some matched attenuator ahead of the receiver input. Twenty feet of RG58 cable will suffice as a matched attenuator.

3. Turn OFF the source and adjust the receiver gain controls to give noise output reading of -10 db on V-O-M scale. Impedance matching may be required to get optimum transfer from receiver to V-O-M.

4. Turn ON source and set its level so receiver output is near 0 db on V-O-M scale. This assures that S/N is high enough not to cause error from noise.

5. Next reduce receiver RF gain to give output reading of -10 db on V-O-M. This is the initial reference point for calibration.

6. Note very carefully the receiver gain control settings and also how sensitive the RF gain control rotation is on output level. If it is very hard to re-set the gain for output level within ±0.5db then it will be necessary to remove the small knob and replace with a large knob preferably having an indexed scale. Or mark the knob so that resetting can be done within ±0.5 db limits. If the gain controls are erratic replace or abandon receiver. It is also wise to let the equipment run at the reference level for a few minutes to see how steady the output level remains. If the level wanders more than ±0.5 db, more drastic stabilization may be required of the source, receiver or both before measurements can be made. Frequency as well as amplitude stability are very important.

7. Starting from the reference gain setting and output reading of -10 db, increase the source level until the receiver output is at 0 db.

8. Turn down RF gain to give output of -10 db

9. Increase source level until receiver output is again 0 db.

10. Repeat steps 8 and 9, 4 times which should increase the signal source level by exactly 40 db ± small errors.

11. After the last increase of source level to give receiver output level of 0 db, disconnect receiver and cable attenuator together from the main line and connect cable to coupled line port. Put good termination on main line where receiver was connected and also another termination on the other end of the coupled line. This latter termination should be kept as a part of the coupler and only this termination used for subsequent measurements with the coupler.

12. With these connections completed the receiver gain control should now be re-set exactly to the reference position. The receiver output may be above or below the 0 db reading.

13. Now carefully adjust the coupling by moving the coupled line closer for more coupling or farther away from the main line for less coupling until the 0 db output reading is again obtained.

Repeat the entire procedure several times for confidence as well as practice in the procedure. The results each time should check within ±0.5 db. Finally, clamp the coupled line or set it securely so that subsequent checks will always give -40db ±0.5 db.

The coupler is now calibrated and may be used for absolute power measurement in conjunction with calibrated low power measuring equipment. If the expected level at the coupled port is higher than the limit of the low power meter, the coupling may be reduced and recalibrated accordingly. If the coupler is only used for VSWR (reflection) measurements, the calibration procedure is not required. Construction as per the drawings will give a coupling coefficient of -40 ± 5 db, which is quite adequate for reflection measurements.

Strip Line Design

This ddsign employs flat material in an easily built strip-line configuration. Figure 1 shows all dimensional details. The main line section is in symmetric strip-line with center conductor a copper strip 0.055 inches thick, nominally 1/16 inch sheet material. The length of the line section shown as 3.5 inches is actually an electrical half-wave long at 1296 mc/s, foreshortened by end loading due to the transition from strip to coax.

The coupled line section is built directly on the BNC receptacles which are screwed into the brass side wall (3/8-32 thread). The mounting holes for this side wall should not be drilled, if calibration is desired, until after the coupling has been set. The 45° mitered corners in the coupled line are characteristic of strip-line technology to preserve impedance around a 90° bend.

The bars which comprise the end walls where the N-type receptacles are located should be assembled first and then top and bottom plates fitted. The main line holes should be drilled undersized (3/8 in) and then taper reamed from the outside until the N-receptacle shoulder fits snugly in to the reamed hole. Retaining screws may now be installed.

Top and bottom plates may be made of copper clad board (copper on inside) if the coupler is not subjected to large physical forces. Squeezing the plates can deform the surfaces enough to cause significant error in coupler calibration (1 db or more.).

Aluminum may be substituted for the brass, in which case all parts should be aluminum to avoid electrolysis.

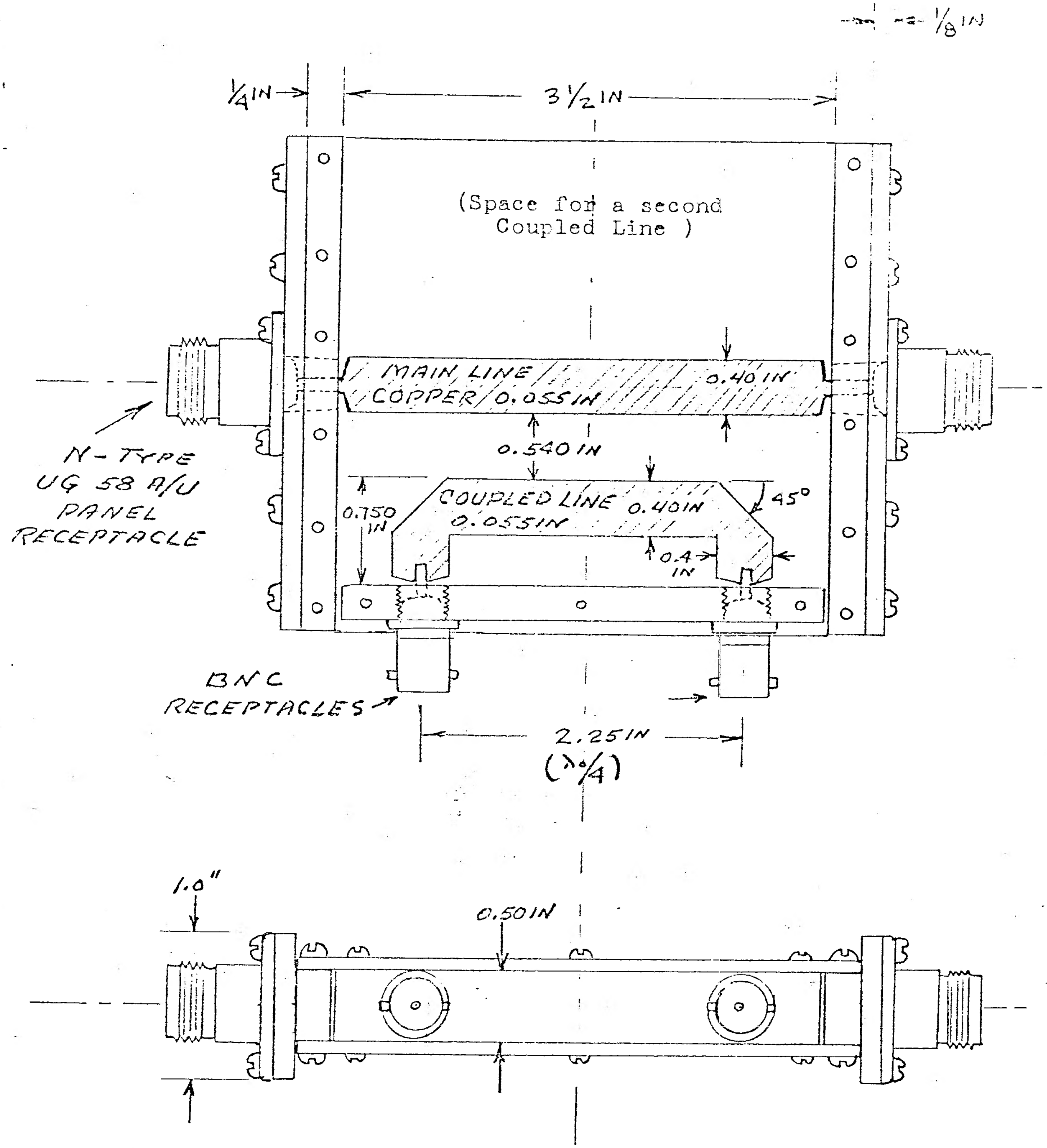
Coax Design

This design shown by Figure 2 is constructed of standard readily available copper water pipe and a 'T' fitting. These are available in most discount department stores, hardware stores and plumbing houses. The N-type connectors are actually panel receptacles (UG 58 A/U) which have been carefully machined down to be a press fit into the copper pipe. The center jack is removed from one of the connectors to allow assembly of the coupler. Simply drive it out with a flat ended rod and hammer in the direction toward the soldered end. The jack is soldered to the main line center conductor separately so that the coupler may be assembled starting from the opposite end.

The main line section is essentially 50 ohm. The Teflon bead at the center of the 'T' is to compensate for the inductive discontinuity of the 'T' arm missing wall. The dielectric bead adds shunt capacitance to tune out the inductive reactance.

The coupled line is actually a short piece of RG 58/U fitted inside of the short soft copper tubes. The coupled region is a very short exposed section of the inner conductor and dielectric. The outer vinyl jacket is stripped away and the coupled section is exposed by carefully pressing the woven wire outer conductor back away from the coupled region without breaking the wires. This may be done after the BNC connectors and line are installed. The coupled assembly is built into a short section of copper pipe with the two bent tubes sweated (soldered) inside the pipe diametrically opposite each other. Install the RG58/U last to avoid overheating of the polyethelene. The BNC connectos may be any of a variety which preserve the impedance integrity (50 ohms). The plane of the coupled line should be parallel with the main line for correct operation as a directional coupler.

The main line assembly does not require soldering if the parts fit together snugly.



HIGH POWER DIRECTIONAL COUPLER 50 ohms

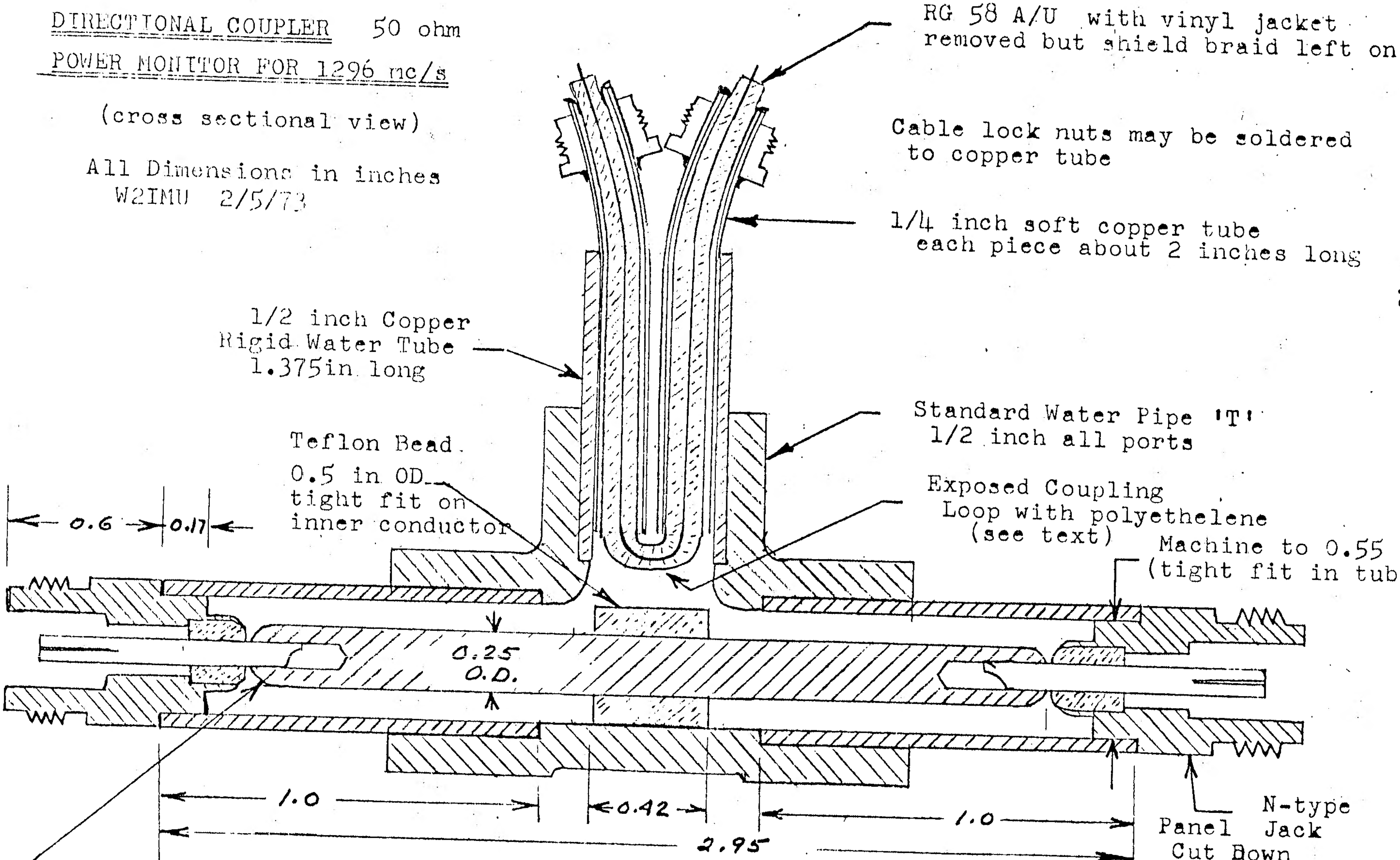
POWER MONITOR FOR 1296 mc/s

DIRECTIONAL COUPLER 50 ohm

POWER MONITOR FOR 1296 mc/s

(cross sectional view)

All Dimensions in inches
W2IMU 2/5/73



If copper tubing is used for center conductor the ends may be slit with hacksaw in six places and then swedged on the connector pin and soldered.